UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

THE ECONOMIC ASSESSMENT OF WATER FLUORIDATION IN SOUTH AFRICA AND ITS IMPACT ON HUMAN RESOURCES AND ORAL HEALTH SERVICE DELIVERY

by

JEROEN KROON

submitted in fulfilment of the requirements for the degree

PHILOSOPHIAE DOCTOR

in the

SCHOOL OF DENTISTRY
FACULTY OF HEALTH SCIENCES
UNIVERSITY OF PRETORIA

APRIL 2008

© University of Pretoria

TABLE OF CONTENTS

TABLE OF CONTENTS i

DECLARATION vi

SUMMARY vii

ACKNOWLEDGEMENTS ix

LIST OF TABLES xi

LIST OF FIGURES xv

LIST OF ABBREVIATIONS xvi

CHAPTER 1: PROBLEM STATEMENT, AIMS, RESEARCH DESIGN AND STRUCTURE 1

1.1 Problem statement 1

1.2 Aims and objectives of the study 5

1.3 Research design 5

1.4 Structure of thesis 6

1.5 Summary 7

CHAPTER 2: LITERATURE REVIEW 8

2.1 Overview of water fluoridation 8

2.1.1 Historical perspective 8

2.1.2 Caries prevention from water fluoridation 13

2.1.3 Recent international reports 14

2.1.4 Water fluoridation in South Africa 18

2.1.5 The economics of water fluoridation 23

2.2 Human resources planning 30

2.2.1 Brief overview 30

2.2.2 Approaches to human resources planning 32

2.2.3 World Health Organization/Fédération Dentaire Internationale planning model 37
2.2.4 A South African perspective on human resources planning 39
2.2.5 Human resources distribution and trends in South Africa 52
2.3 South African policy documents on health and oral health service delivery 58
2.3.1 Transformation of health services 58
2.3.2 National Oral Health Policy 60
2.3.3 Primary oral health care package 63
2.4 Summary 65

CHAPTER 3: COST EVALUATION OF THE IMPLEMENTATION OF WATER FLUORIDATION IN SOUTH AFRICA 66
3.1 Introduction 66
3.2 A model to calculate per capita cost, cost-effectiveness and cost-benefit of the implementation of water fluoridation in South Africa 66
3.2.1 Chemical cost (Variable Group (A)) 70
3.2.2 Labour cost (Variable Group (B)) 75
3.2.3 Maintenance cost (Variable Group (C)) 78
3.2.4 Opportunity cost (Variable Group (D)) 81
3.2.5 Capital depreciation (Variable Group (E)) 81
3.2.6 Operating cost (Variable Group (F)) 82
3.2.7 Total cost (Variable Group (G)) 82
3.2.8 Per capita cost (Variable Group (H)) 83
3.2.9 Caries prevalence (Variable Group (I)) 84
3.2.10 Cost-effectiveness (Variable Groups (J)) 85
3.2.11 Cost- benefit (Variable Groups (K)) 85
3.3 Results 86
3.3.1 Total cost of water fluoridation 87
3.3.2 Per capita cost 89
3.3.3 Cost-effectiveness 92
3.3.4 Cost-benefit 94
3.4 Discussion 97
3.4.1 Introduction 97
3.4.2 Total and per capita cost of the introduction of water fluoridation 99

3.4.3 Cost-effectiveness....102
3.4.4 Cost-benefit....103
3.5 Summary....104

CHAPTER 4: COST EVALUATION OF DELIVERING THE MINIMUM PACKAGE OF ORAL CARE TO SOUTH AFRICAN CHILDREN....106
4.1 Introduction....106
4.2 A model to calculate the per capita cost of delivering the minimum package of oral care....106
4.2.1 Population size (Variable [1])....107
4.2.2 Treatment need (Variable [2])....107
4.2.3 Treatment fees (Variable [3])....114
4.2.4 Monetary value for each treatment need type (Variable [4])....119
4.2.5 Total expense to address treatment need (Variable [5])....120
4.2.6 Total per capita cost to address treatment need (Variable [6])....120
4.2.7 Percentage of total cost for each treatment need type (Variable [7])....120
4.2.8 Per capita cost of each treatment need type (Variable [8])....120
4.3 Results....120
4.4 Discussion....126
4.4.1 Introduction....126
4.4.2 Per capita cost of delivering the minimum package or oral care to South African children....128
4.5 Summary....130

CHAPTER 5: ORAL HEALTH HUMAN RESOURCES NEEDS FOR SOUTH AFRICAN CHILDREN....131
5.1 Introduction....131
5.2 World Health Organization/Fédération Dentaire Internationale human resources planning model....131
5.2.1 Restorative care, arresting care and extractions (Variable Group (A))....134
5.2.2 Treatment time requirements (Variable Group (B))....136
5.2.3 Human resources calculations (Variable Group (C))....141
5.2.4 Impact of the implementation of water fluoridation....142
5.3 A “Service Targets Method” model to calculate human resources....142

5.3.1 Minutes of need (Variable Group (A)) 144
5.3.2 Minutes of demand (Variable Group (B)) 148
5.3.3 Human resources calculations (Variable Group (C)) 148
5.3.4 Impact of the implementation of water fluoridation 149
5.4 Results 149
5.4.1 Background information 149
5.4.2 Total human resources 150
5.4.3 Oral hygienists 155
5.4.4 Dental therapists and dentists 155
5.5 Discussion 158
5.5.1 Introduction 158
5.5.2 Oral health human resources required on a national level 160
5.5.3 Oral health human resources required on a provincial level 162
5.6 Summary 163

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS 165
6.1 Conclusions 165
6.1.1 Cost evaluation of the implementation of water fluoridation in South Africa 165
6.1.2 Cost evaluation of delivering the minimum package of oral care to South African children 167
6.1.3 Oral health human resources needs for South African children 169
6.2 Recommendations 173

BIBLIOGRAPHY 177

ANNEXURES 187
ANNEXURE 1: PER CAPITA COST, COST-EFFECTIVENESS AND COST-BENEFIT OF THE IMPLEMENTATION OF WATER FLUORIDATION FOR THE CITY OF TSHWANE METROPOLITAN MUNICIPALITY (PRETORIA) 187
ANNEXURE 2: DETAILED INFORMATION ON WATER PROVIDERS 189
ANNEXURE 3: PER CAPITA COST OF DELIVERING THE MINIMUM PACKAGE OF ORAL CARE TO THE 15-YEAR-OLD AGE COHORT 195

ANNEXURE 4: THE WORLD HEALTH ORGANIZATION/FéDéRATION DENTAIRE INTERNATIONAL HUMAN RESOURCES PLANNING MODEL: NATIONAL REQUIREMENTS TO DELIVER THE MINIMUM PACKAGE OF ORAL CARE TO 4- TO 15-YEAR-OLD SOUTH AFRICAN CHILDREN 205

ANNEXURE 5: A “SERVICE TARGETS METHOD” MODEL FOR HUMAN RESOURCES PLANNING: REQUIREMENTS TO DELIVER THE MINIMUM PACKAGE OF ORAL CARE TO 4- TO 15-YEAR-OLD SOUTH AFRICAN CHILDREN 207

DECLARATION

I, Jeroen Kroon, declare that the thesis, "THE ECONOMIC ASSESSMENT OF WATER FLUORIDATION IN SOUTH AFRICA AND ITS IMPACT ON HUMAN RESOURCES AND ORAL HEALTH SERVICE DELIVERY", which I hereby submit for the degree Philosophiae Doctor at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

_____

Jeroen Kroon

April 2008

SUMMARY

THE ECONOMIC ASSESSMENT OF WATER FLUORIDATION IN SOUTH AFRICA AND ITS IMPACT ON HUMAN RESOURCES AND ORAL HEALTH SERVICE DELIVERY

by

JEROEN KROON

Supervisor:	**Professor PJ van Wyk**
Department:	**Community Dentistry**
Degree for which the thesis is submitted:	**Philosophiae Doctor**

Water fluoridation has been confirmed by three recent reviews as one of the most cost-effective and safe primary preventive measure against dental caries. Despite this evidence no artificially fluoridated water scheme exists in South Africa. The economic impact of water fluoridation in times of a reduction in dental caries should be weighed against its benefits. A minimum package of oral care has been proposed for implementation in the public oral health services. Irrespective of the implementation of water fluoridation and/or a minimum package or oral care, it will impact on the required oral health human resources.

The aim of this study was to investigate the economic viability of the implementation of water fluoridation and the delivery of the minimum package of oral care and the impact this will have on human resources planning for oral health in South Africa.

Computerised simulation models were developed for this study. Per capita cost, cost-effectiveness and cost-benefit of the implementation of water fluoridation was calculated for seventeen major metropolitan cities, towns and water boards in South Africa. Treatment need data was converted to a per capita cost to express the delivery of the minimum package of oral care as a monetary value. The World Health Organization/Fédération Dentaire Internationale and a “Service Targets

Method" model were used to calculate the oral health human resources required to deliver the minimum package of oral care.

The average per capita cost of water fluoridation for the total population is R2.08. At an anticipated 30% caries reduction achieved with water fluoridation, average cost-effectiveness is R33.16 and cost-benefit was calculated as 0.18. Cost-benefit equals or exceeds 0.8 for only three municipalities or water boards at an anticipated 10% caries reduction as a result of the implementation of water fluoridation.

The average per capita cost to provide the minimum package of oral care is R245.95 without the impact of water fluoridation and R186.03 at an anticipated 30% caries reduction due to water fluoridation.

Oral hygienists represent more than 50%, dental therapists between 30 to 40% and dentists less than 10% of the total oral health human resources required to deliver the minimum package of oral care. At an anticipated caries reduction of 30% due to the introduction of water fluoridation, the number of dentists required decrease by 29%, dental therapists between 27.5 and 29.8% and oral hygienists between 2.1 and 10.5%. This converts to a saving in salaries of R14,8 million per year.

It is recommended that water fluoridation remains a viable option for South Africa, even if only a 10% caries reduction as a result of its introduction is achieved. All provinces should actively pursue the introduction of the minimum package of oral care with appropriate modes of delivery by creating a number of posts as well as incentives to attract especially oral hygienists and dental therapists to the public service. The impact of the introduction of water fluoridation on human resources should always be considered in planning the number of oral health professionals to be trained.

ACKNOWLEDGEMENTS

"Your biggest break can come from never quitting. Being at the right place at the right time can only happen when you keep moving toward the next opportunity."
Arthur Pine

I wish to express my sincere gratitude and appreciation to the following people for their contribution and assistance in this study:

My supervisor, Prof Flip van Wyk, Head of the Department of Community Dentistry, University of Pretoria, for his support, encouragement, guidance and constructive criticism throughout and also for being a mentor, friend and colleague.

Prof Flip van Wyk, Ms Sannie Booyens and Dr Pratima Kissoon-Singh, whose research on water fluoridation and human resources planning served as the inspiration for this study.

Prof Tshepo Gugushe, Dean of the School of Dentistry, University of Limpopo and Prof Newell Johnson, Foundation Dean and Head of the School of Dentistry and Oral Health, Griffith University, for allowing me the time to complete this study while employed at their institutions.

Staff from municipalities, local authorities and water boards for providing me with the information needed for this study.

Mr Eddy Valkenburgh and Mr Martin de Klerk, Pelchem, and Peter Leopold, Süd-Chemie, for information on the cost and transport of fluoride chemicals.

Ms Marica Erasmus, Department of Water Affairs and Forestry, for allowing me access to their database on natural fluoride concentrations.

Dr Johan Smit, Director Oral Health, Department of Health, for his support and interest.

Mrs Susan Marsh, Department of Library Services, University of Pretoria, for always being there when assistance was required.

Mrs Wilma Steinbach, Oral and Dental Hospital, University of Pretoria, for providing me with information and her patience with explaining the UPFS fee schedule.

Mrs Gollie Venter, Personal Assistant, Department of Community Dentistry, University of Limpopo, for her assistance and encouragement in sometimes difficult times.

Professor Peter Cleaton-Jones and Prof Elly Grossman, Dental Research Institute, University of the Witwatersrand, for providing me with opportunities and introducing me to the wonderful world of research so many years ago which has culminated in this thesis.

Professor Willie Snyman, previous Head of the Department of Community Dentistry, University of Pretoria, for his role in my development, his advice and leadership over a number of years.

My wife, Amanda, for her love, understanding, support and dedication to our family which has carried me through this study.

My son, Marco, whose enthusiasm for and dedication to the things I also love kept me motivated to complete this study.

My daughter, Rianca, for just being the daughter every father wishes for and for keeping the balance in the family.

My parents, I dedicate this thesis to you for providing me with the opportunities in life.

My friends and other family members, for their understanding during the past number of years.

Soli Deo Gloria

LIST OF TABLES

Table 1: Summary of early studies into the relationship between fluoride in community water supplies, dental caries and dental fluorosis 8
Table 2: Savings in cost of dental treatment, working time and cost-benefit analysis for water fluoridation studies in five countries (Davies, 1974) 25
Table 3: Cost evaluation of the implementation of water fluoridation in Gauteng (Van Wyk et al., 2001) 29
Table 4: Summary of advantages, disadvantages and indications of the four approaches to human resources planning (Hall, 1978; Kissoon-Singh, 2001) 35
Table 5: Summary of landmark human resources developments in South Africa from 1910 to 1993 (Van Wyk, 1996) 40
Table 6: Human resources required for the delivery of oral health services in South Africa based on the WHO/FDI model (Booyens, 1996) 43
Table 7: The need for oral health personnel in South Africa by 2011 (Van Wyk, 1996) 44
Table 8: Human resources requirements for KwaZulu-Natal (2000 and 2010) for selected procedures of the basic oral health care package (Kissoon-Singh, 2001) 48
Table 9: Magisterial districts with the lowest and highest operator to population ratios in South Africa (Van Wyk et al., 1994) 53
Table 10: Number and percentage of South African dental graduates, first year students and dental specialists by gender and racial group (Lalloo et al., 2005; Lalloo et al., 2006) 56
Table 11: Oral health professionals registered with the HPCSA on 30 March 2007 (Health Professions Council of South Africa, 2007) 58
Table 12: Recommended ratios for oral health personnel in the public sector (Department of Health, 1999) 63
Table 13: The minimum package of oral care (Department of Health, 2001a; Pick et al., 2001) 64
Table 14: A model to calculate per capita cost, cost-effectiveness and cost-benefit of the implementation of water fluoridation 68

Table 15: Properties of the three commonly used fluoridation chemicals (Department of Health, 2003c; Pelchem, 2007) 70
Table 16: Number of water purification plants and daily water purification rate per municipality or water board 72
Table 17: Natural fluoride content of municipalities and water boards (Erasmus, 2004; Grobler et al., 2006) 73
Table 18: Total delivery cost of chemical per metric tonne (De Klerk, 2006; Leopold, 2006) 75
Table 19: Average operator salary, number of operators required, annual operator salary and annual labour cost 78
Table 20: Capital cost for a water fluoridation plant for Category A, B and C water providers 80
Table 21: Operating and total cost of water fluoridation 82
Table 22: Caries prevalence (DMFT) for 15-year-olds per district and province: 1999-2002 NCOHS 84
Table 23: Average cost of a two surface restoration (Council for Medical Schemes, 2006) 86
Table 24: Cost of the introduction of water fluoridation 87
Table 25: Per capita cost of water fluoridation for the total population and those younger than fifteen years 90
Table 26: Cost-effectiveness of water fluoridation 92
Table 27 : Cost-benefit of water fluoridation 95
Table 28: A model to calculate per capita cost of delivering the minimum package of oral care 107
Table 29: 2006 South African mid-year population estimates by province (Statistics South Africa, 2006) 107
Table 30: Example of calculation of mean weighted national values 109
Table 31: Percentage treatment need for 4- to 5-, 6-, 12- and 15-year-olds for all provinces 110
Table 32: Treatment need per tooth for 4- to 5-, 6-, 12- and 15-year-olds for all provinces 111
Table 33: Prevalence and severity of periodontal disease (bleeding and calculus only) for 15-year-old South African children (Department of Health, 2003b) 114
Table 34: Treatment need values used in this study 114

Table 35: UPFS oral health procedure and consultation fees for middle (H2) and high (HG) income patients (Gauteng Provincial Government, 2005) 117
Table 36: NRPL and UPFS fees used in this study 118
Table 37: Summary of treatment need variables and NRPL/UPFS codes and fees used in this study 119
Table 38: National per capita cost of delivering the minimum package of oral care by age cohort 122
Table 39: Impact of water fluoridation on the average national per capita cost of delivering the minimum package of oral care (including examination and bitewing radiographs) 123
Table 40: Impact of water fluoridation on the average national per capita cost of delivering the minimum package of oral care (excluding examination and bitewing radiographs) 124
Table 41: Impact of an oral examination and bitewing radiographs on the average national per capita cost of delivering the minimum package of oral care 125
Table 42: Mean per capita cost of delivering the minimum package of oral care per province 126
Table 43: The WHO/FDI model to calculate human resources required to deliver the minimum package of oral care (World Health Organization/Fédération Dentaire Internationale, 1989) 133
Table 44: Caries prevalence of 4- to 5- and 15-year-old South African children: 1999-2002 NCOHS (Department of Health, 2003b) 135
Table 45: Mean number of sextants with bleeding and calculus in 15-year-old South African children (Department of Health, 2003b) 138
Table 46: Utilization of services based on time elapsed since previous visit to a dentist or dental clinic for the South African adult population (Department of Health, 1994) 140
Table 47: 2006 South African mid-year population estimates for the 4- to 5- and 6- to 15-year-old age cohorts (Statistics South Africa, 2006) 142
Table 48: A “Service Targets Method” model to calculate human resources needed to deliver the minimum package of oral care 144
Table 49: Treatment need as a percentage of the population or mean number of teeth/sextants for the 4- to 15-year-old age cohort 145
Table 50: Treatment times used in the “Service Targets Method” model 146

Table 51: Summary of human resources requirements for 4- to 15-year-old South African children calculated with the WHO/FDI and “Service Targets Method” models 151
Table 52: Difference between human resources requirements for 4- to 15-year-old South African children calculated with the WHO/FDI and “Service Targets Method” models 153
Table 53: Requirements for oral hygienists for 4- to 15-year-old South African children using the WHO/FDI and “Service Targets Method” models..... 156
Table 54: Requirements for dental therapists and dentists for 4- to 15-year-old South African children using the WHO/FDI and “Service Targets Method” models..... 157
Table 55: Summary of recommendations from this study 176

LIST OF FIGURES

Figure 1: The health manpower system (Mejía and Fülöp, 1978) 31
Figure 2: Schematic representation of the four approaches to human resources planning (Hall, 1978) 33
Figure 3: Flow chart of the WHO/FDI human resources planning model (World Health Organization/Fédération Dentaire Internationale, 1989) 39
Figure 4: Location of cities, towns and water boards..... 67
Figure 5: Cost of the introduction of water fluoridation for Category A, B and C municipalities and water boards as a percentage of the total cost 89
Figure 6: Per capita cost for the total population and those younger than fifteen years for Category A, B and C municipalities and water boards 91
Figure 7: Cost-effectiveness of water fluoridation for the total population for Category A, B and C municipalities and water boards at three anticipated levels of caries reduction 93
Figure 8: Cost-effectiveness of water fluoridation for those younger than fifteen years for Category A, B and C municipalities and water boards at three anticipated levels of caries reduction..... 93
Figure 9: Cost-benefit of water fluoridation for the total population for Category A, B and C municipalities and water boards at three anticipated levels of caries reduction 96
Figure 10: Cost-benefit of water fluoridation for those younger than fifteen years for Category A, B and C municipalities and water boards at three anticipated levels of caries reduction..... 96
Figure 11: National human resources requirements calculated with the WHO/FDI model for delivering the minimum package of oral care to 4- to 15-year-old South African children 154
Figure 12: National human resources requirements calculated with the “Service Targets Method” model for delivering the minimum package of oral care to 4- to 15-year-old South African children..... 154

LIST OF ABBREVIATIONS

ANC	African National Congress
ART	Atraumatic Restorative Technique
BER-BCI	Bureau for Economic Research's Building Cost Index
CBA	Cost-benefit analysis
CCS	Compulsory Community Service
CEA	Cost-effectiveness analysis
CEO	Chief Executive Officer
CPI	Community Periodontal Index
CPITN	Community Periodontal Index of Treatment Need
CSIR	Council for Scientific and Industrial Research
CSS	Central Statistics Service
DASA	Dental Association of South Africa
dmft/DMFT	decayed, missing and filled teeth
FDI	Fédération Dentaire Internationale
FTE	Full-time equivalents
GDC	General Dental Council
HPCSA	Health Professions Council of South Africa
IADR	International Association for Dental Research
JFIC	Joint Fluoridation Implementation Committee
MEDUNSA	Medical University of Southern Africa
MRC	Medical Research Council
NAMDA	National Medical and Dental Association
NCOHS	National Children's Oral Health Survey
NFC	National Fluoridation Committee

NHRP	National Human Resources Plan for Health
NOHS	National Oral Health Survey
NRPL	National Reference Price List
PHC	Primary Health Care
ppm	parts per million
SAAWU	South African Association of Water Utilities
SADA	South African Dental Association
SADJ	South African Dental Journal
SALGA	South African Local Government Association
SAMDC	South African Medical and Dental Council
STATOMET	Bureau for Statistical and Survey Methodology
UK	United Kingdom
UPFS	Uniform Patient Fee Schedule
USA	United States of America
WHO	World Health Organization